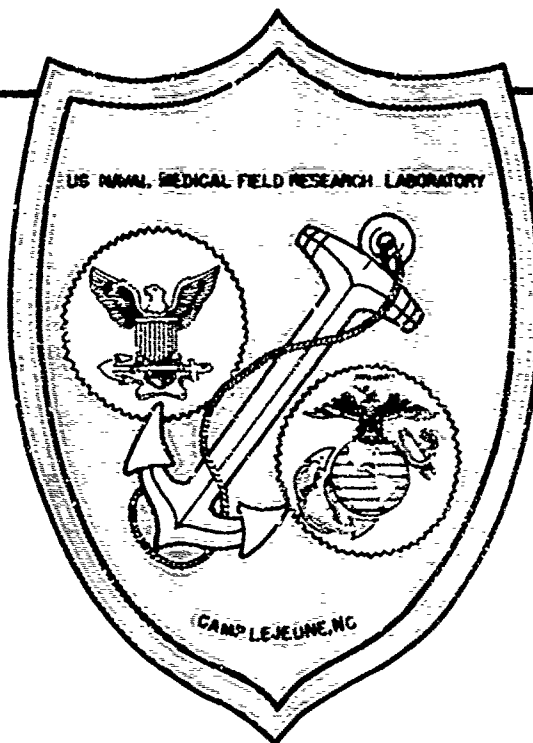


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AN INNOVATION IN MOSQUITO-BORNE DISEASE PROTECTION

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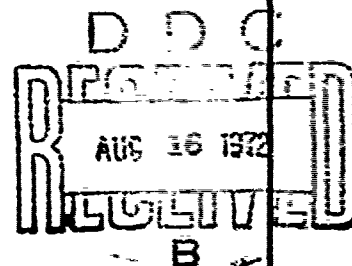
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13. ABSTRACT <p>Part experience has shown that there is a great need to protect the individual combat soldier from vector-borne diseases. Because of the unique problems encountered in combat, personal protection of the individual has proven to be the most practical means of reducing vectored diseases. Many different chemical repellents and barrier devices have been used, but all of them have failed to provide the necessary level of protection.</p> <p>Wide mesh netting treated with a "space repellent" such as diethyl toluamide was found to provide excellent protection from biting insects. The netting excluded insects, but allowed air to move in sufficient amounts for good ventilation. Both hearing and sight were improved over old style netting. Specific tests on bed nets revealed that both 100 percent cotton and 50 percent cotton/50 percent polyester fabrics withstood three to five years in storage with little loss in tensile strength. Exposure to the environment for up to six weeks did not visibly increase deterioration time. Both types of fabric appeared acceptable with respect to life expectancy in storage and field use. (U)</p>			

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An Innovation in Mosquito-borne Disease Protection

LCDR Roger H. Grothaus, MSC, USN*
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With the advent of World War II, the American military establishment found itself poorly prepared to cope with the disastrous problem of vector-borne diseases. During the first Solomon Islands offensive, the 1st Marine Division had 10,635 casualties from 7 August to 10 December 1942; only 1,472 were from gunshot wounds. Five thousand seven hundred forty-nine men were put out of action by malaria. The United States Army also suffered great losses to malaria. It is estimated that the time lost by Army combat personnel in the Pacific Theater amounted to 10,140,372 man days. The United States Navy reported 11,272 cases in its personnel.¹

When military commanders realized the magnitude of their problem, specific steps were taken to break the cycle of transmission between man and mosquitoes. Malaria control units of different types were established, and entomologists were quickly located and directed to work on the problem. It was during this period that military entomology became a distinct and unique specialty.

The success of military entomology was best attested by Rear Admiral Lamont Pugh, MC, USN, who said, "the anti-malaria unit was responsible for the implementation of a program in the South Pacific which conserved more manpower and perhaps saved more lives than all the surgeons in the Armed Forces combined."² The spectacular results of the preventive medicine-entomology effort caused the military establishment to commission both operational and research units devoted to protecting US forces from vector borne disease.

Research and Drug Therapy

After World War II, research on insect vectors continued at a steady pace. American forces were tasked with global responsibilities and were exposed to almost every known vector-borne disease. Major research effort was directed toward malaria because of the historical impact of the disease on military operations. The development of a preventive drug regimen for malaria was a direct result of continued research. This drug regimen was undoubtedly responsible for the virtual nonexistence of malaria in Korea. The savings in manpower and life in this military conflict more than justified the cost of the research involved in developing the drug prophylaxis and suppressant.

Unfortunately, the success of antimalarial drugs somewhat dulled the emphasis on mosquito protection and control techniques. Even though most authorities considered the Culicidae to be the single most important family of arthropods in the world, vector research moved forward at a rather routine pace with no great degree of urgency.^{3,4} Progress has been

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made in military entomology, but much of the basic information has yet to be applied to actual field use. Military entomologists have learned through experience that transmission of mosquito-borne pathogens is greatly increased in areas exposed to the chaos of combat. It has also been learned that mosquito-borne diseases are best controlled by breaking the cycle of transmission through control or personal protection. In combat operations, medical reserves are heavily committed and it becomes impossible to "clinically clear" the human reservoir in single host diseases. Considerable progress has been made in developing control techniques in noncombat situations. However, these techniques have not always proven acceptable in military situations. Because of the problems involved in combat situations, special equipment has been developed to provide the desirable level of control. Development of aerial spray systems for the rapid treatment of large areas is one of the control techniques which shows much promise for the military establishment.⁵ The development of personal protection techniques has been another means of breaking the transmission cycle of diseases such as malaria. The most commonly used protective items in the field have been bed nets and repellents.⁶

Personal Protection Techniques

In the current conflict in Southeast Asia, the development of drug resistance by the species *Plasmodium falciparum* has caused great and sudden importance to be placed on the use of personal protection techniques and mosquito control. The problem has been further complicated by the change in the type of warfare encountered. Area control has proven difficult without stable "front lines." Chemical treatment and ecological manipulation of breeding areas can not be completely accomplished without total and continuous access to the territory involved. In addition, field personnel have found it difficult to maintain acceptable levels of repellent on the exposed portions of the body, and standard bed and head nets have been found to be inconvenient and uncomfortable.⁹ Past experiences have shown that the use of nets and protective clothing is of little value in reducing malaria under patrol conditions.¹⁰

Beginning 1965-66 the Naval Medical Field Research Laboratory began placing major emphasis on mosquito-borne disease control, with the goal of solving some of the problems occurring in Southeast Asia. Considerable priority was placed on developing protective devices that would have a high degree of troop acceptability and still maintain a high degree of mosquito repellency. The laboratory's initial "break-through" occurred when the US Department of Agriculture, Agricultural Research Service Laboratory at Gainesville, Florida, began reexamination of their repellent program and started a search for chemicals that would be effective at a distance. These chemicals became known as "space repellents." Various ways were devised to use the chemicals,

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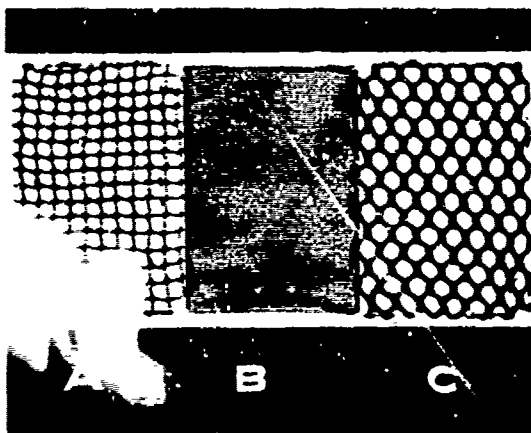


Fig. 1. (A) Wide mesh knotted cotton netting; (B) Standard fine mesh netting; (C) Cotton/polyester netting.

but the most promising was with wide mesh cotton netting.⁶ Presently, the most commonly used mosquito netting has 8-11 threads/cm (21-28 mesh/in). The wide mesh nets currently being tested are 0.635 cm or four mesh/in). The standard small mesh netting prohibits the flow of air, interferes with sight and reduces hearing, all of which limits troop acceptability. The wide mesh netting concept involves the utilization of the material in the netting as a reservoir for the chemical repellent, which produces a vapor barrier between the openings. The most successful combination has been four-mesh cotton netting weighing more than 0.0077 gm/cm². The repellents currently available have not proven effective in protecting openings greater than 0.635 cm; however, netting of this type allows air to move in amounts sufficient for good ventilation.⁴ Because of the advantages of the new netting several research groups have been working on different items, including mosquito net jackets.⁷



Fig. 2. Bed net constructed of cotton and polyester fiber.



Fig. 3. Head net constructed of wide mesh netting.

Materials and Methods

The task of developing practical field items using wide mesh netting involved two research procedures. One series of tests was needed to determine the best type of fabric for use by the military. The second study was designed to locate an acceptable chemical for use on the nets. The project was organized so that both test phases interlocked, resulting in savings of both manpower and time.



Fig. 4. Wide mesh, all-purpose net on tent.

Initial studies revealed that synthetic fabrics were not acceptable, because they failed to absorb the required volume of repellent during impregnation. Some work was attempted with nylon impregnation while the nylon was still in a liquid state. When this form of treatment was utilized, the repellent was not released and the proper vapor barrier was not achieved. For this reason, nets used in the field tests were of two basic types. The first type of net was 100 per cent cotton. Both knotted (fishnet) and pressed cotton were studied. The second net type was composed of 50 per cent cotton and 50 per cent polyester fiber (Fig. 1). It was hoped that this material would prove to have adequate tensile strength and storage life and still retain the required level of repellent.

The storage life of the different types of material was tested by placing treated and untreated nets in plastic bags and storing them at room temperature. The nets were removed periodically from 1966 to 1971 and examined. Some nets were reintroduced into the field repellency tests to obtain observed data on their ability to withstand troop use. One series of nets was exposed to the outside environment for five weeks before packaging. They were exposed to a total of 25.4 cm of rain during this period. Another series of nets was exposed to outside air for six weeks and then packaged.

Field tests against wild mosquitoes were conducted by fabricating the various types of netting into standard sized military bed nets (Fig. 2). Each type of net was compared with the other type when a specific repellent was being tested. All series contained untreated nets as checks. During the field tests, groups of men were taken to areas containing high numbers of mosquitoes. Each man erected his net so that all nets were in a straight line, upwind from the mosquito resting areas. The men entered their nets about one-half hour before sunset and remained there until one hour after sunset, since this was the peak mosquito activity period. Each man used a small pen light and an aspirator to collect the mosquitoes that entered his net. Collections were made in increments of 15 minutes. One man served as an outside control during each series of tests. All of the mosquitoes were identified as to species. The total per cent effectiveness of the nets was obtained by comparing the net data with the outside control data.

The total length of each field test was somewhat variable, because of the fluctuation of the mosquito population. The tests were designed to run one night a week for six weeks, provided mosquitoes were present. The six weeks time period was chosen rather arbitrarily, but it seemed reasonable to conclude that nets and chemicals would have to survive for this minimum period before they could be considered for military use. Chemicals that showed much promise during their first screening were held over for the next summer's study. In this way, long-lived repellents were given adequate exposure. Items other than bed nets have been fabricated and tested with the same basic procedure as that used in the bed net studies.

Discussion

The studies involving "net life" were oriented to provide the authors with some insight into the problems that might be encountered in standardizing such items as bed nets. Shelf life of the items was of prime consideration. One hundred per

TABLE I
EFFECTIVENESS OF N,N-DIETHYL-META-TOLUAMIDE TREATED BED NETS
AGAINST FIELD MOSQUITO POPULATIONS*

Total Weekly Tests	Total Mosquitoes Collected	Average No. Mosquitoes Collected Net Night	Average No. Mosquitoes Collected Night Outside Control	Per Cent Effectiveness
40	95	2.4	158	98.5**

* Each net was tested for four to six weeks depending on the mosquito population.

** Nets were treated at the rate of 0.5 gm repellent / gm fabric.

cent knotted cotton nets placed in storage in 1966 were still visibly unchanged and usable in 1971. These nets lost little or no tensile strength during the five-year storage period. The nets in this series were treated with N, N-diethyl-meta-toluamide before storage. It is not known if this repellent enhanced the life of the netting. More importantly, the chemical did not apparently accelerate deterioration of the fabric. Several nets stored for three to four years were removed and used in field tests to see if they would withstand troop handling. All nets to date have remained unharmed after 10 to 18 nights' use. Nets exposed to the external environment were found to be unharmed after three years in storage. The 50/50 nets were placed in the program in 1969, and have exhibited no deterioration or other undesirable characteristics. Pressed cotton nets were found to perform adequately under research conditions, but did not withstand excessive troop handling. The pressed nets were pulled and the even spacing of the threads was disrupted under rough handling.

Most of the bed nets used in the storage tests were those that had been treated and replaced in plastic bags at the end of a particular season. With some repellents, especially N, N-diethyl-meta-toluamide, the surfaces of the enamel-painted storage shelves were damaged by the nets. The plastic bags permitted vapor to escape, which caused the paint to disintegrate. The standardizing of these nets using this chemical will require packaging designed to avoid the release of the repellent.

Several chemicals have been tested and found to provide excellent results. The authors have selected one chemical as the recommended repellent for bed nets. This chemical, diethyl toluamide, is currently in the military supply system. It is used as a skin repellent and is, therefore, available to the field soldier. The availability of this repellent in the field ensures that it will be possible to re-treat the nets when necessary. The use of diethyl toluamide as a space net repellent was studied in over 40 tests (Table I). Nets containing this chemical were 98.5 per cent effective for a four to six-week period. In one test, two treated nets were tested for six weeks and repackaged until the next summer, when they were again tested against field mosquitoes. Both nets provided over 90 per cent effectiveness for four weeks. Bed nets treated with diethyl toluamide effected good repellency response from all of the mosquito species encountered (Table II). Some work with this combination has been conducted in the tropics. Diethyl toluamide treated nets were used in Thailand and

TABLE II
MOSQUITO SPECIES KNOWN TO BE REPELLED BY
REPELLENT-TREATED WIDE MESH NETTING

Genus	Species	Genus	Species
<i>Aedes</i>	<i>atlanticus</i>	<i>Anopheles</i>	<i>barberi</i>
	<i>canadensis</i>		<i>crucians</i>
	<i>cinereus</i>		<i>quadrimaculatus</i>
	<i>juxta pallens</i>	<i>Culex</i>	<i>erraticus</i>
	<i>infernatus</i>		<i>nigripalpus</i>
	<i>sollicitans</i>		<i>pipiens quinquefasciatus</i>
	<i>terniorhynchus</i>		<i>salinarius</i>
	<i>triseriatus</i>		
<i>Psorophora</i>	<i>fallax</i>		
	<i>confinis</i>		
	<i>jeffersoni</i>		

found to provide complete protection for *Aedes aegypti* and *Culex pipiens quinquefasciatus* for 16 to 17 weeks.³ The exact life of the repellent was not determined during the research period, because the repellency response differed with different species. Temperature and other climatic factors also affected the life of the chemical. The data did indicate that re-treatment every two months would provide almost complete protection.

Preliminary results have indicated that the proper net-chemical combination will provide acceptable protection in almost any configuration. Head nets were tested (Fig. 3) and provided acceptable mosquito protection, while greatly improving sight, hearing and general comfort. Drop nets for tents, bunkers and other field shelters have also been designed (Fig. 4), but have not been tested for effective life. Mosquito shirts were constructed of the 50/50 fiber and were found to prevent biting, but field troops had some difficulty moving through heavy brush. These shirts were found to be particularly desirable to radio operators, because the net effectively covered the radio, making it extremely difficult to locate through field glasses. Additional tests using diethyl toluamide treated shirts (body nets) were conducted in Gambela, Ethiopia, during 1970. The nets provided excellent protection against *Culex univittatus neavi*, *Mansonia africana*, *M. uniformis*, *Aedes albopictus* and *A. triseriatus*. The members of the field research team utilized the body net for sleeping at times, and found that it provided good protection without being objectional from a comfort standpoint. The team did find some objection to the odor when the shirts were worn in a closed, hot trunk.

Summary

Past experience has shown that there is a great need to protect the individual combat soldier from vector-borne diseases. Because of the unique problems encountered in combat, personal protection of the individual has proven to be the most practical means of reducing vectored diseases. Many different chemical repellents and barrier devices have been used, but all of them have failed to provide the necessary level of protection.

Wide mesh netting treated with a "space repellent" such as diethyl toluamide was found to provide excellent protec-

tion from biting insects. The netting excluded insects, but allowed air to move in sufficient amounts for good ventilation. Both hearing and sight were improved over old style netting. Specific tests on bed nets revealed that both 100 per cent cotton and 50 per cent cotton/50 per cent polyester fabrics withstood three to five years in storage with little loss in tensile strength. Exposure to the environment for up to six weeks did not visibly increase deterioration time. Both types of fabric appeared acceptable with respect to life expectancy in storage and field use.

Nets treated with diethyl toluamide provided excellent protection against all mosquitoes encountered. Protection time was found to be in excess of six weeks without re-treatment. It was found that nets could be stored for at least one year and still retain enough repellent to provide in excess of 90 per cent protection. Other items, such as head nets and shirt nets, were found to provide the same degree of protection as the treated bed nets. Wide mesh netting provided protection equal to older items without the disadvantages. Increased comfort, sight and hearing greatly improved troop acceptance of protective items constructed of wide mesh netting.

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